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NATURAL GAS COMPRESSOR STATION PIPELINE WELDING AND RELATED FACILITIES

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Abstract- *Compressor station is the fundamental facility of a natural gas transmission pipeline network. Gas transmission pipelines are used to transport gas from one region to another. During the transportation of gas, after a certain interval (40 to 100 miles), gas pressure is reduced tremendously. To increase gas pressure as well as flow, compressor station is necessary. In gas transmission network, normally centrifugal compressor is used. The main reason is that a centrifugal gas compressor can handle a large amount of gas with increased pressure. The compression ratio of a centrifugal compressor is low usually less than 2.0. In Bangladesh there are three compressor stations (Muchai, Ashuganj and Elenga). Major power stations and Fertilizer plants in Bangladesh are getting gas with more pressure after the installation of these three compressor stations. The welding of compressor station pipelines is very difficult. Highly qualified welders (6G) are required for compressor station pipeline welding. Generally higher thickness pipelines are used in compressor station. Codes and standards used for compressor station pipeline welding are more stringent. Shock and vibration are two common phenomena in a compressor station. An adequate knowledge and sagacity are required for selecting compressor station materials, resorting NDT methods and testing of pipelines.*

Keywords: Compressor Station, Welding, 6G, NDT.

1. INTRODUCTION

A Compressor Station project has been done with pipes from Ø 0.5 inch to Ø 46 inch diameter or higher depending upon the station capacity. Pipes from Ø 0.5 inch to Ø16 inch diameter are ASTM A 106 B SMLS BE [1] material pipe. The minimum yield strength of ASTM A 106 B pipe is 35,500 psi (415MPa). Station inlet manifold pipe thickness is more than 2 inch as per design criteria. Generally Ø24, Ø30, Ø40, Ø46 inch or higher diameter pipelines are API-5L-B-PSL 2 SAW BE [2] material pipe. The minimum yield strength of API-5L-B-PSL 2 SAW BE pipe is 35,500 psi (415MPa). For Tie-In works (pipe connection between existing gas grid pipeline and compressor station pipeline) API-5L-X60-PSL 2 SAW BE material pipes are used. The minimum yield strength of API-5L-X60-PSL 2 pipe is 60,200 psi (515MPa).

2. WELDING

As per AWS [3], a welding process is "a materials joining process which produces coalescence of materials by heating them to suitable temperatures with or without the application of pressure or by the application of pressure alone and with or without the use of filler material". For welding procedure qualifications, ASME BPVC Section IX [4] is used. GTAW (Gas Tungsten Arc Welding) and SMAW (Shielded Metal Arc Welding) processes are used for compressor station pipelines welding. Welding terminologies are shown below:

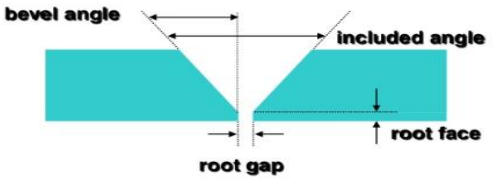

Fig.1: Single V butt joint
Courtesy: TWI [5]

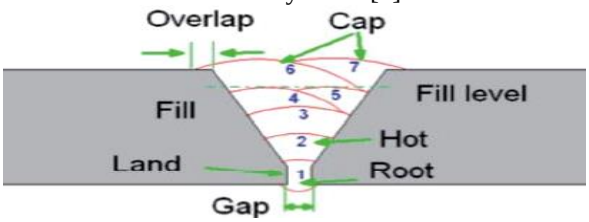

Fig.2: Welding layer (Courtesy: Internet)

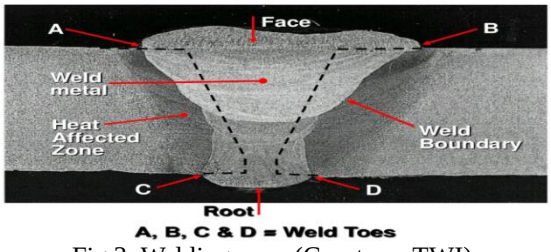

Fig.3: Welding zone (Courtesy: TWI)

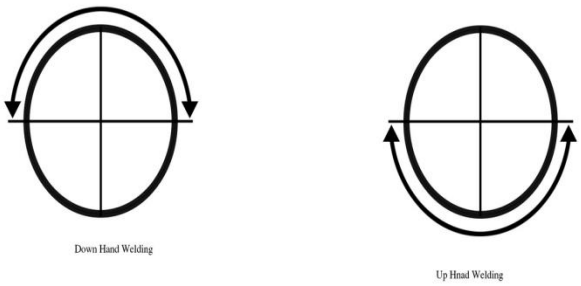

Fig.4: Welding Progression Down-hill and Up-hill (Courtesy: Internet)

For pipe diameter Ø2 inch or less, GTAW process is used. Pipe diameter from Ø3 inch to higher diameter, combined welding processes (GTAW+SMAW) are applied. For root and hot passes GTAW process; fill and cap passes SMAW process.

2.1 GTAW/TIG WELDING

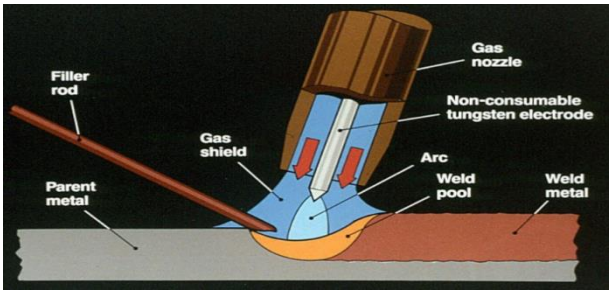

Fig.5: GTAW welding (Courtesy: TWI)

For carbon steel, base metal number i.e. P No. is 1 and Group No. is 1, single V butt joint. Filler Metal Number i.e. F No. for GTAW is 6. Weld metal chemical composition number i.e. A No. is 1 for mild steel. SFA No. for GTAW is 5.18 [6] and AWS No. ER 70S-G. "ER" stands for either an Electrode or Rod. "70" is the minimum tensile strength of the weld metal produced by the electrode in ksi. "S" means that filler metal is solid. "G" indicates that as agreed between supplier and purchaser. Shielding Gas is Argon. Filler metal sizes are Ø1.6 and 2.0 mm. Recommended electrical polarity for GTAW is DCEN as per ASME Section IX, 2010 edition. Thoriated non-consumable Tungsten electrode is used during GTAW welding.

2.2 SMAW WELDING

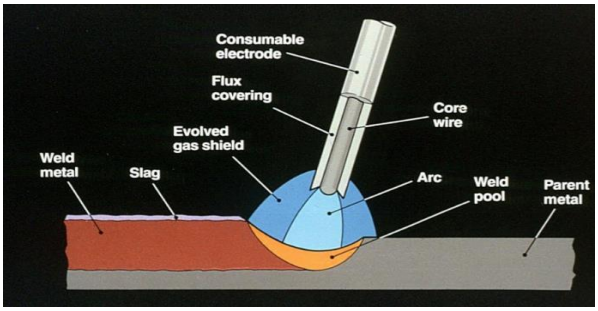

Fig.6: SMAW Welding (Courtesy: TWI)

F No. for SMAW is 4, A No. 1, SFA No. 5.1 [7], AWS No. E7018. "E" designates electrode. "70" means minimum tensile strength of weld metal in ksi. "1" stands for all position welding. "8" posits that diffusible hydrogen content average 8 ml/100 g deposited metal. Filler metal sizes are Ø3.2 and 4.0 mm. Recommended electrical polarity for SMAW is DCEP. Welding progression is Up-hill for both GTAW and SMAW processes. Up-hill progression makes stronger welding joints compared to down-hill.

2.3 ESSENTIAL VARIABLES

Essential variables are P No., F No., A No., AWS class, maximum thickness qualified, PWHT, welding progression etc. Any change in those specific variables, mechanical properties of the weldment are affected and requalification of the WPS shall be required.

2.4 NON ESSENTIAL VARIABLES

Non essential variables are groove design, root gap, backing, filler metal size, string/weave, method of cleaning, preheat etc. Any change in the non essential variables may be made in the WPS without requalification.

2.5 PREHEAT

It is a good practice to pre-heat the job before welding of carbon steel pipes. Pre-heat removes moisture from the pipe surface. For site welding, pre-heating is done by torch burner or induction heater coil. To check the pre-heat temperature, temperature sensitive materials are used.

Fig.7. Temperature sensitive crayons (courtesy: TWI)

Table 1: Preheat Requirements according to ASME B 31.3 [8], 2010 edition, page: 66

Preheat Temperatures

Base Metal P-No. or S-No. [Note (1)]	Weld Metal Analysis A-No. [Note (2)]	Base Metal Group	Nominal Wall Thickness		Specified Min. Tensile Strength, Base Metal		Min. Temperature Required		Min. Temperature Recommended	
			mm	in.	MPa	ksi	°C	°F	°C	°F
1	1	Carbon steel	< 25	< 1	≤ 490	≤ 71	...	...	10	50
			≥ 25	≥ 1	All	All	...	...	79	175
			All	All	> 490	> 71	...	...	79	175

Defects associated with lack of preheating are shown below:

Fig.8: Crack on the flange-neck

Fig.9: Micrograph showing welded joints and crack in the base metal

3. NDT (NON DESTRUCTIVE TESTING)

NDT includes visual inspection, Dye penetrant test, Magnetic particle inspection, Radiographic and Ultrasonic test. Visual Inspection is an observation of pipeline, components and other elements before, during and after welding, fabrication or testing. Only external flaws of a welding are identified with visual inspection. External flaws are undercut, excessive reinforcement, weld spatter, hi-low etc. The duty of welding inspection personnel is to confirm that all the welding and related activities are performed as per specified code, standard and procedure.

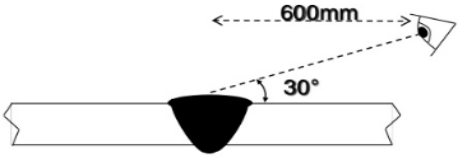

Fig.10: Visual Inspection (Courtesy: TWI)

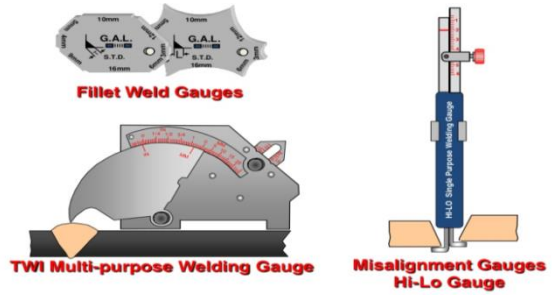

Fig.11: Welding Inspector's gauges (Courtesy: TWI)

When a joint is visually accepted, then Radiographic and Ultrasonic testing are performed to evaluate inside joint imperfections like porosity, cluster porosity, lack of penetration, lack of fusion, slag inclusions, crack etc.

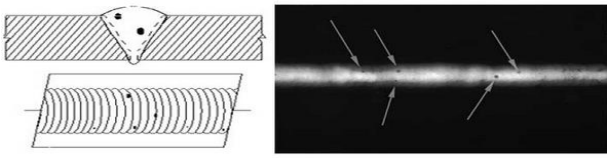

Fig.12: Porosity (Courtesy: Internet)

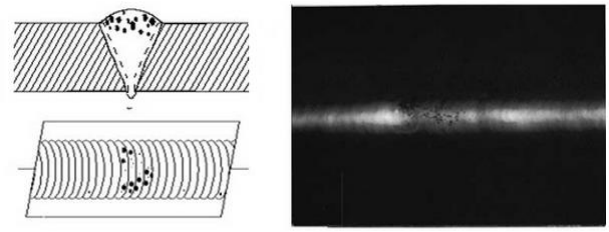

Fig.13: Cluster porosity (Courtesy: Internet)

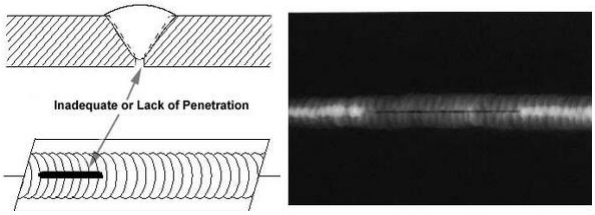

Fig.14: Lack of penetration (Courtesy: Internet)

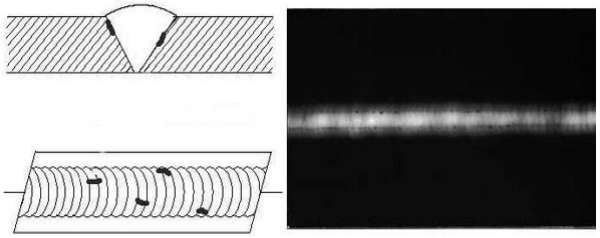

Fig.15: Lack of fusion (Courtesy: Internet)

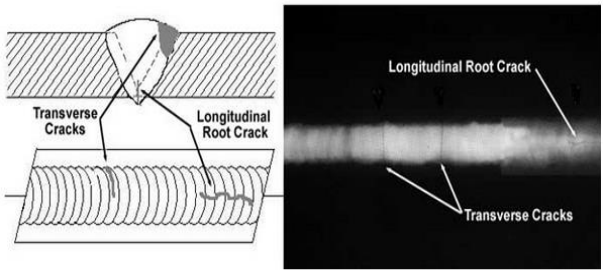

Fig.16: Crack (Courtesy: Internet)

Service gas pipeline is designed for high pressure (1135 psi). Few pipe spools are designed for medium pressure (150 to 360 psi) and these are mainly fuel gas line and fire water line. Vent line, oily water sewerage lines are designed for low pressure (open to atmosphere). High pressure pipe spools are 100% radiographed. Acceptance criteria for evaluating welding imperfections as per ASME B 31.3 Process Piping code.

3.1 POST WELD HEAT TREATMENT (PWHT)

Post Weld Heat Treatment (PWHT) is a key requirement for higher thickness pipeline welding.

During welding of higher thickness pipes, stress is induced in the joint. If stress remained in the joint and in severe cyclic operation i.e. in Compressor Station, there is a possibility of a welding joint failure. To remove stress from the welding joint, Post Weld Heat Treatment is performed. Joint toughness is also increased after PWHT, which is very important requirement for severe cyclic operation. Two types of heat treatment: one is Furnace Heat Treatment and another is Local Heat Treatment.

Fig.17: Induction heater arrangement for Local PWHT

Fig.18: Insulation around the joint

Fig.19: Local PWHT controller

Table 2: Post weld heat treatment requirement, ASME B31.3 Process piping code 2010 edition, Table 331.1.1 page: 67

Requirements for Heat Treatment

Base Metal P-No. or S-No. [Note (1)]	Weld Metal Analysis A-Number [Note (2)]	Base Metal Group	Nominal Wall Thickness mm	Nominal Wall Thickness in.	Specified Min. Tensile Strength, Base Metal MPa	Specified Min. Tensile Strength, Base Metal ksi	Metal Temperature Range °C	Metal Temperature Range °F	Holding Time Nominal Wall [Note (3)] min/mm	Holding Time Nominal Wall [Note (3)] hr/in.	Holding Time Min. Time, hr	Brinell Hardness, Max. [Note (4)]
1	1	Carbon steel	≤ 20	≤ 3/4	All	All	None	None	...	...	...	...
			> 20	> 3/4	All	All	593–649	1,100–1,200	2.4	1	1	...

ASME B 31.3 code avers that PWHT is mandatory for carbon steel when thickness is more than 20 mm. Holding time is 2.4 minute per millimeter thickness. Holding temperature range is 593 to 649°C.

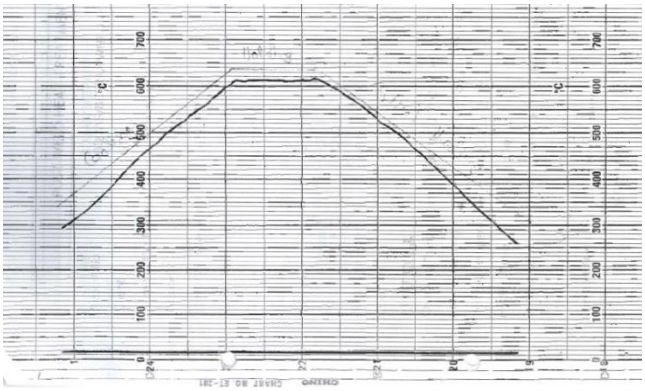

Fig.20: Typical PWHT graph

3.2 HARDNESS

As per ASME B 31.3 "The hardness limit applies to the weld and to the heat affected zone (HAZ) tested as close as practicable to the edge of the weld. (a) Where a hardness limit is specified in Table 331.1.1, at least 10% of welds, hot bends, and hot formed components in each furnace heat treated batch and 100% of those locally heat treated shall be tested." All Local PWHT joints are accomplished hardness test.

Table 3: Hardness values for different materials

Material Specification	Hardness Value (maximum)
ASTM A 105 [9]	187 HB
ASTM A 234 [10]	197 HB
ASTM A 860 [11]	235 HB
Welds of P-1 Material as per API RP 582[12]	225 HB
API 5L Line pipe for Grades ≤ L450 or X65	≤ 270 HV10 or ≤ 25 HRC
ASTM A 106 Grade B	271 HB or 290 HV10.

ASTM A 694 F 60[13]	197 HB

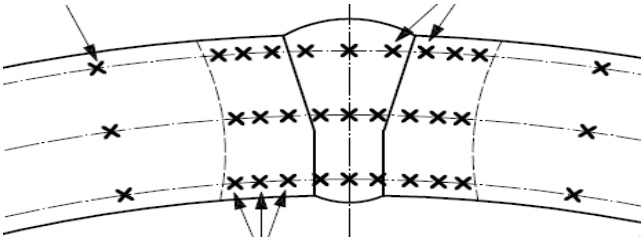

Fig. 21: Location of Hardness Test (Courtesy: API 5L, 45th edition)

Fig. 22: Digital Hardness Tester (Courtesy: GE measurement and control)

4. HYDROSTATIC TEST AND PNEUMATIC TEST

Hydrostatic and pneumatic tests are observed to check the integrity of pipelines. According to ASME B 31.3 the hydrostatic test pressure is 1.5 times the design pressure. The test medium and test duration shall be as per the Natural Gas Safety Rules.

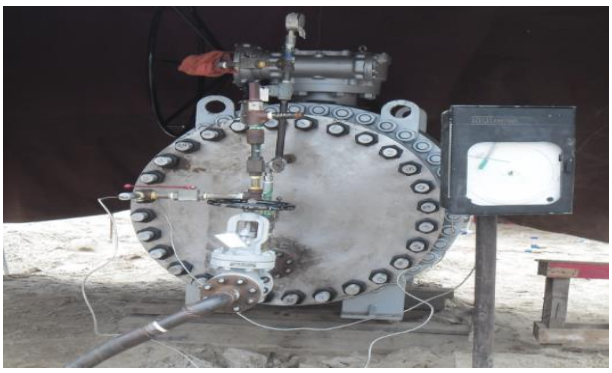

Fig.23: Hydrostatic test arrangement

For plant air pipeline, pneumatic test is completed. The pneumatic test pressure is conducted 1.2 times the design pressure. The test medium and the test duration shall be as per the Natural Gas Safety Rules. Test records are included: test date, test medium, piping system specification, duration of test, test pressure, employer acknowledgement and examiner certification of test results.

5. CONCLUSION

During the welding, all essential variables are checked thoroughly. To check these variables is the main duty of a Welding Inspector. ASME BPVC gives more priority on safety. Compressor Station pipeline welding inspection is really a challenging job. Code, Standard, Procedure, Specification, Design, Drawing and Gantt chart are followed strictly to complete a Compressor Station Project within the specified budget and time limit. Reliability, safety, smooth operation and overall performance of the Compressor Station depend on welding and related facilities.

6. REFERENCES

[1] Standard Specification for Seamless Carbon Steel Pipe for High Temperature Service (ASTM A 106).
[2] API 5L: Specification for Line Pipe (45th edition).
[3] American Welding Society (AWS).
[4] ASME BPVC Section IX: Qualification Standard for Welding and Brazing Procedures, Welders, Brazers, and welding and Brazing Operators.
[5] http://www.twi-global.com/
[6] Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding (SFA 5.18).
[7] Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding (SFA 5.1).
[8] ASME B 31.3: Process Piping Code, 2010 edition.
[9] Standard Specification for Carbon Steel Forgings for Piping Applications (ASTM A 105).
[10] Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service (ASTM A 234).
[11] Standard Specification for Wrought High-Strength Low-Alloy Steel Butt Welding Fittings (ASTM A 860).
[12] Welding Guidelines for Chemical, Oil, and Gas Industries API Recommended Practice 582, 2009 edition.
[13] Standard Specification for Carbon and Alloy Steel Forgings for Pipe Flanges, Fittings, Valves, and Parts for High-Pressure Transmission Service (ASTM A 694).

7. NOMENCLATURE

Symbol	Meaning
ASTM	American Society of Testing Materials
SMLS	Seamless
BE	Bevel End
SAW	Submerged Arc Welding
PSL	Product Specification Level
ASME	American Society of Mechanical Engineers
BPVC	Boiler and Pressure Vessel Code
ksi	Thousand Pound per Square Inch
WPS	Welding Procedure Specification
HAZ	Heat Affected Zone
HB	Brinell Hardness
HV	Vickers Hardness
HRC	Rockwell Hardness C Scale